The Washington Post

CORRECTION TO THIS ARTICLE

An earlier version of this story incorrectly stated that neutrinos have no mass, but in fact they have almost no mass. It also said neutrinos are not bent by gravity, which can bend light and other forms of radiation. In fact, neutrinos are not bent by electric and magnetic fields, which can bend other forms of radiation. This version has been corrected.

IceCube opens up a window on energy in the universe

By Eric Niiler
Special to The Washington Post
Monday, February 7, 2011; 1:59 PM

AMUNDSEN-SCOTT BASE, ANTARCTICA -
The world's newest astronomical observatory is defined by a field of 86 colored flags rippling across an ice-covered polar landscape. Each banner marks a line of glass-covered orbs that stretches down a mile and a half into the ice, like beads on a frozen string.

Known as IceCube, this massive underground array is designed to do what no other observatory has done before - catch a glimpse of elusive neutrinos, ghostly particles that are formed in the hearts of supernovas, black holes and other deep-space objects and may give scientists new information about the origins of the universe.

"The idea with IceCube is to do astronomy, but instead of using light, we're using neutrinos," said Greg Sullivan, a physicist at the University of Maryland who is one of the collaborators on the $279 million project.

"It opens up a window on energy in the universe," he explained. "We've seen particles in outer space that are 10 million times more energetic than the ones we can accelerate on Earth. Neutrinos are a way to try and find out what's causing those very high energy [particles]. It's been a mystery for 100 years."

Astronomers have flocked to the South Pole in the winter for decades, drawn by the sunless skies and atmospheric conditions that make superb star-gazing. A permanent U.S. station has been at the pole since 1956, and several telescopes have been built here to take advantage of the darkness that lasts from late February to early October.

But IceCube is something different, an observatory built entirely beneath the ice. Along each of the 86 cables are strung 60 three-foot spherical detectors, called digital optical modules or DOMs. These glass-covered orbs are designed to find evidence of neutrinos - particles formed in the hearts of stars that are so small they pass right through the Earth (and our bodies) without hitting molecules or other matter.

Since neutrinos have almost no mass and are too small to be seen with a normal telescope, researchers instead are looking for the extremely small and extremely brief flashes of bluish light that are given off when a neutrino's energy trail strikes an oxygen atom in the ice and creates a third particle, called a muon.

"We thought that if we could . . . detect that light, we could reconstruct the direction and energy of that muon, which would give us the direction of the neutrinos," Sullivan said during a visit last month to the South Pole sponsored by the National Science Foundation.

In the past, scientists have tried to build neutrino detectors in the deep ocean, abandoned mine shafts and the bottom of deep lakes. All the projects failed for different reasons: salt corroded the detectors, for example, or the muon trails were obscured by the natural light given off by plankton.

Astrophysicists have high hopes for the South Pole location. One advantage of the massive icepack is that it provides a "scaffolding . . . infrastructure for the detectors," holding them steady, Jonathan Feng, a particle physicist and cosmologist at the University of California at Irvine, explained in a phone interview. It also presented extreme challenges: Constructing IceCube involved more than 400 technicians and engineers and took seven summers of tough drilling through polar ice.

IceCube's detectors are pointed northward, toward the center of the Earth, so the planet's mass serves as a filter to block most cosmic rays and other particles. Feng noted that in addition to passing through most matter, neutrinos also are not bent by electric and magnetic fields, which can bend other forms of radiation - potentially bringing information more directly from farther corners of the universe.

The National Science Foundation picked up $242 million of Ice Cube's $279 million price tag. The rest was split among science agencies from Germany, Sweden and Belgium, which also cooperated on construction. The University of Wisconsin at Madison, the project's lead institution, coordinated the design, build and software to run it. The university is also coordinating the data distribution, making information available to scientists around the world.

Now that IceCube is up and running, Feng says he's especially interested in what it might reveal about dark matter, mysterious material that scientists postulate makes up five-sixths of the mass of the universe, but which has never been detected directly.

"The entire periodic table is just small fraction of total matter in the universe," Feng said. "The rest is dark matter but it doesn't reflect light or shine light. We don't see it the way we see stars."

When dark matter particles inside the sun and other stars collide with each other, neutrinos are created. If IceCube can detect these neutrinos and glean useful data about where they come from, Feng said, "there will be hundreds of scientists jumping up and down to see if it's a signal of dark matter."

Credit for coming up with the idea behind IceCube is generally given to Francis Halzen, a theoretical physicist at the University of Wisconsin. In the late 1980s, Halzen was intrigued by the problem of building a neutrino detector and had studied the failure of other projects. Interviewed at his office in Madison, Halzen said he's forgotten his "eureka" moment back in 1987.

"One of my former graduate students says I told him one morning coming out of the elevator," Halzen said. "But I really don't remember. I didn't realize that I would spend most of the rest of my career doing this."

Halzen got together with colleagues at the University of California at Berkeley and began planning a pilot project, called the Antarctic Muon and Neutrino Detector Array, or AMANDA. It began operation at the South Pole in 1993, but only laid a few strings of detectors into the ice.

IceCube, which was conceived in 1999 as a collaboration between U.S. and European agencies, was on a much grander scale. Engineers on the project ran into formidable obstacles.

"You can't just buy a drill in Texas and bring it to Antarctica," Halzen said. "We had to figure all these things out."

During the first year summer of drilling in 2004-05, technicians laid only one string of detectors, and Halzen said they nearly gave up. But a University of Wisconsin team developed a special drill that used hot water to drill nearly two miles deep into the ice. Once cooled, the water was pumped back to the surface, reheated and recycled in a closed-loop system. Then the huge hose that carried the water kept breaking under its own weight.

"It was a struggle," Halzen said. Finally, one of the engineers found a firm in Venice with the right equipment, "and we eventually made it work."

There were also logistical challenges. Because of limited space at the South Pole station, the IceCube team could deploy no more than 40 workers at a time. Construction crews had to be rotated in by a three-hour flight from the main U.S. facility at McMurdo Station. "It was like solving a crossword puzzle," Halzen said. "Everything and everyone had to fit just perfectly."

By the 2008 drilling season, they had put in 20 strings of detectors. The 86th and final string was laid Dec. 19.

IceCube has already found a strange asymmetry to cosmic rays reaching Earth from the southern hemisphere from the direction of a supernova named Vela.

"Nobody knows what it means; that's why its interesting," Halzen said.

For all his work in pushing to get IceCube built, Halzen has never been to the South Pole. During the building phase, he said, he was loath to take up valuable space that could have been used for an engineer or construction worker.

"I have had no use to go there, but maybe now," Halzen said. "Last week it was colder here in Madison that at the South Pole."

health-science@washpost.com